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ORIGINAL STUDY

External application of hypertonic salt solution for treatment of posttraumatic oedema

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In 20 New Zealand rabbits (two groups of 10 rabbits each), hind limb circumference and anterior compartment pressure were measured following ketamin anaesthesia (time zero). During the same anaesthesia, closed transverse proximal tibial shaft fractures were created in both groups. Twenty-four hours after the fractures, during a second anaesthesia, limb circumference and compartment pressure were measured as before, and fractured limbs were fixed to the rabbits' bodies. At the same time, treatment was started : one group received external application of saturated salt solution and the other group received intermittent ice application.

During 48 hours of treatment (from 24 to 72 hours) in the saturated salt solution group, the mean limb circumference decreased from 125.70 ± 9.93 mm to 115.70 ± 8.78 mm (p = 0.005) and the mean compartment pressure decreased from 18.30 ± 1.70 mmHg to 12.40 ± 1.77 mmHg (p = 0.005). In the control group, the mean limb circumference decreased from 127.85 ± 7.47 mm to 122.00 ± 6.83 mm (not significant) and the mean compartment pressure decreased from 19.57 ± 1.27 mmHg to 17.85 ± 2.67 mmHg (not significant). In short, differences in compartment pressure and limb circumference before and after treatment were statistically significant in the saturated salt solution group (p = 0.005) but not in the control group.

Keywords : posttraumatic oedema ; treatment ; salt solution.

INTRODUCTION

The pathogenesis of posttraumatic oedema has not been clearly defined (*16*). Various treatment modalities have been used for posttraumatic oedema (*2, 7, 8, 15*). One characteristic of oedema is the collection of water in tissues, and with this in mind we considered the possibility of using osmosis to treat oedema.

When a hypertonic medium is separated from a hypotonic medium by a semi-permeable membrane, fluid movement continues until the osmotic pressures in the two compartments are equalised (*3*). In our experiment the skin served as the

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semi-permeable membrane. Previous studies have shown that fluid can be lost from the skin, and this is known as insensible fluid loss (*3, 11, 14*). It has also been demonstrated that the concentration of externally applied NaCl solutions affect the uptake of water across the human skin in direct proportion to their molarity (*5*). Water can cross the skin in either direction, and two tendencies are involved : the skin's tendency to absorb water due to fluid-solid interactions, and the tendency of water to flow toward regions of higher salt concentration. We hypothesised that if an externally applied solution has a high enough salt concentration, there can be a net loss of water across the skin.

Based on this phenomenon of skin osmosis, the goal of this study was to investigate the effectiveness of hypertonic salt solution applied externally to the skin for the treatment of posttraumatic oedema.

MATERIALS AND METHODS

After approval was given by the institutional "animal care and use" committee, 20 male New Zealand rabbits with a mean weight of 3.1 ± 0.4 kg were obtained. They were randomly assigned to two groups : a study group in which oedema would be treated with saturated salt solution, and a control group in which oedema would be treated with ice application. The difference in mean weight between the two groups was not statistically significant. Following ketamin anaesthesia (45 mg/kg given intramuscularly), the right hind limb was shaved and a point at 1 cm distal to the knee was marked with permanent ink (time zero). Limb circumferences were measured at the marked level to evaluate oedema as previously described (*6, 12*). Anterior compartment pressures were measured with the method described by Whitesides *et al*, which is easy and reliable (*13, 18*). Values were obtained for each animal at least twice with this technique. Then, through the application of pure bending force, transverse proximal tibial shaft fractures were created (*4*). All fractures were examined radiologically. Three rabbits in the control group were not evaluated : one of them died and the other two had inappropriate fractures. In order to encourage oedema, the fractures were initially not fixed.

Twenty-four hours after the fracture, each rabbit was again given ketamin anaesthesia, and limb circumference and compartment pressure were measured as before. Immediately after the measurements, the fractured limbs were fixed to the rabbits' bodies (fig 1) and treatment was started. The fractured limbs were fixed to the trunk with the hip joint flexed and the knee joint extended. For the group receiving saturated salt solution treatment, 50 g of NaCl was put into water-permeable pockets made of cotton fabric measuring 10 cm × 10 cm. These were wet thoroughly with saturated salt solution and were applied to the fractured limbs (one pocket per rabbit). In each rabbit the pocket was placed so as to completely surround the fractured limb, and was kept in place with gauze roll bandages. The pockets were soaked with saturated salt solution 8 times a day, which was sufficient to keep them continuously wet. The osmolality of the resulting solution next to the skin was approximately 12.000 mOsm/kg, which is that of saturated NaCl solution at room temperature (24° C). In the control group, ice was applied to the fractured limbs for half an hour, four times a day (total 2 hours), with the bandage remaining in place. The external compression exerted by the bandage was made as alike as possible in both groups.

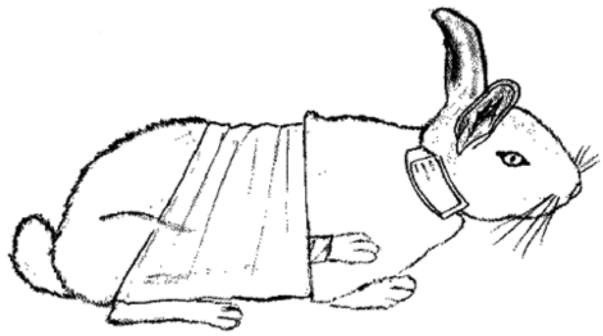

Fig. 1. — The fractured limb was fixed with gauze roll bandages, in both groups.

In summary, the authors measured hind limb circumferences and compartment pressures before the fractures (time zero), at 24 hours after the fractures (immediately before the treatment started), at 48 hours after the fractures (i.e. after 24 hours of treatment) and at 72 hours after the fractures (i.e. after 48 hours of treatment). All measurements were performed under ketamin anaesthesia.

For statistical analysis, Wilcoxon's signed rank test was used to compare the intra-group measurements, and the Mann-Whitney U test to compare the inter-group measurements. Calculations were made with SPSS for Windows (SPSS 10.0.1 SPSS, Inc.).

Table I. — Oedema Parameters in the Groups

	Hind limb Circumference (in mm)		Compartment Pressure (in mmHg)	
	Hypertonic Solution Group X ± SD (N = 10)	Control Group X ± SD (N = 7)	Hypertonic Solution Group X ± SD (N = 10)	Control Group X ± SD (N = 7)
Hour 0 (Before fractures)	97.30 ± 8.53 (86.00-110.00)	97.14 ± 10.46 (88.00-116.00)	8.70 ± 1.82 (6.00-11.00)	9.85 ± 3.38 (6.00-14.00)
Post-fracture hour 24	125.70 ± 9.93 (110.00-138.00)	127.85 ± 7.47 (117.00-137.00)	18.30 ± 1.70 (16.00-22.00)	19.57 ± 1.27 (18.00-21.00)
Post-fracture hour 48*	115.20 ± 8.09 (103.00-125.00)	124.28 ± 10.37 (111.00-144.00)	12.70 ± 1.76 (10.00-16.00)	17.85 ± 2.03 (14.00-20.00)
Post-fracture hour 72**	115.70 ± 8.78 (102.00-131.00)	122.00 ± 6.83 (115.00-133.00)	12.40 ± 1.77 (9.00-14.00)	17.85 ± 2.67 (13.00-21.00)

* After 24 hours of hypertonic salt solution or ice administration ; ** After 48 hours of hypertonic salt solution or ice administration.

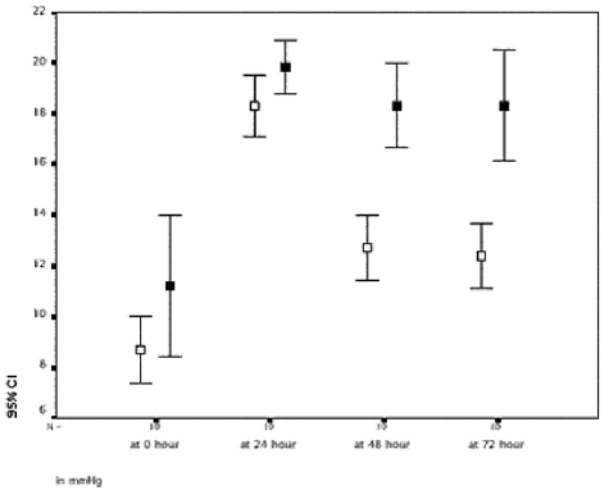

Fig. 2. — Compartment pressure was measured at four moments ;
□ indicates study group.
■ indicates control group.
Ordinate : compartment pressure in mm Hg (from 6 to 22 mm).

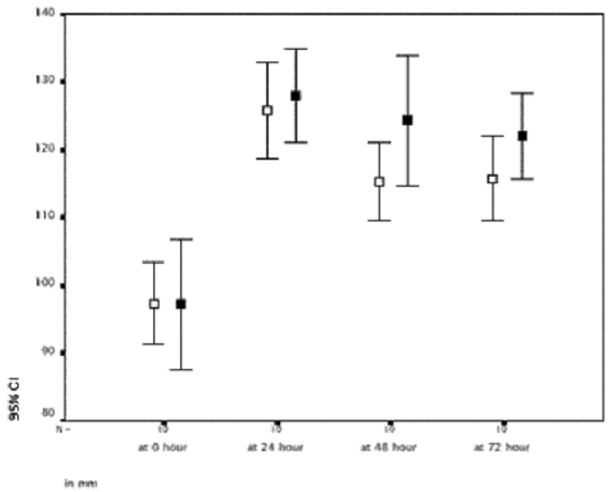

Fig. 3. — Limb circumference was measured at four moments ;
□ indicates study group.
■ indicates control group.
Ordinate : limb circumference in mm (from 80 to 140 mm).

RESULTS

Table I shows the hind limb circumferences and compartment pressures measured in both groups.

Before the fractures, the two groups did not differ significantly in terms of hind limb circumferences or compartment pressures. At 24 hours after the fractures, these values were significantly increased within both groups ($p = 0.005$) but did not differ significantly between the two groups.

In the group treated with saturated salt solution, hind limb circumferences (fig 3) were significantly reduced ($p = 0.005$) at 48 and 72 hours post-fracture, i.e. after 24 and 48 hours of treatment, compared to the baseline oedema measured at 24 hours post-fracture. In the control group, no significant reductions in limb circumference were found. Reductions in anterior compartment pressures (fig 2) were likewise significant in the salt solution group ($p = 0.005$), but not in the control group, at 48 and 72 hours post-fracture, i.e. after 24 and 48 hours of treatment.

DISCUSSION

When searching the literature for treatments of oedema that use external hypertonic solutions, we found no studies related to musculoskeletal trauma. However, it has been reported that in patients with incarcerated rectal prolapse, externally applied sugar granules can reduce tissue oedema and result in spontaneous bowel reduction (*10*). This effect is apparently due to osmosis.

Although the pathogenesis of posttraumatic oedema has not been clearly defined, various methods have been used for its treatment. In our experimental study we wanted to examine the possibility that hypertonic salt solution can reduce posttraumatic oedema by promoting the loss of water through the skin by osmosis. In humans, approximately 300-400 ml of water is lost from the skin daily, and this can be seen even in people who congenitally have no sweat glands (*3*).

Ice application has been used for a long time for the treatment of oedema in musculoskeletal injuries (*2, 7*). Recent studies have shown that ice application prevents oedema, not by vasoconstriction but mostly by impeding leukocyte adhesion (*1, 2, 9*).

In this experiment our aim was not to prevent oedema formation but to treat the oedema that formed. Hence, we waited 24 hours for the formation of oedema before we applied the treatment. In the group treated with saturated salt solution, we found decrease in both limb circumferences and compartment pressures, and we attribute this to a loss of water through osmosis. This seems reasonable considering the large difference in osmolality involved. The osmolality of the saturated salt solution was approximately 12.000 mOsm/kg, while that of mammalian extracellular fluid is approximately 300 mOsm/kg (*17*). Posttraumatic oedema is one of the factors that increase compartment pressure (*13*). In the control group we also found decreases in limb circumferences and compartment pressures but they were not statistically significant.

In summary, our aim was to study whether the local application of hypertonic solution might be effective for the treatment of posttraumatic oedema. The significant reductions in oedema parameters seen in the study group suggest that this possibility should be explored further in view of its potential application in the treatment of musculoskeletal injuries.

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